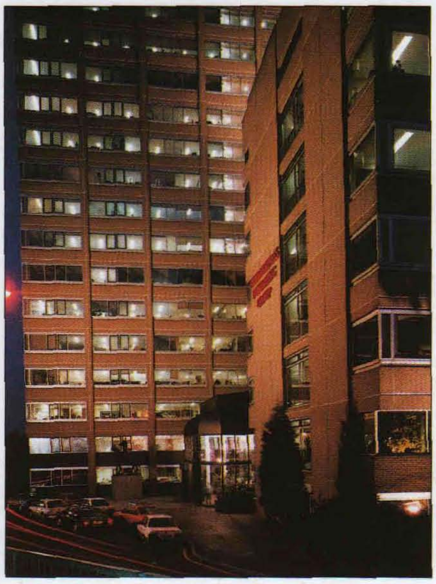
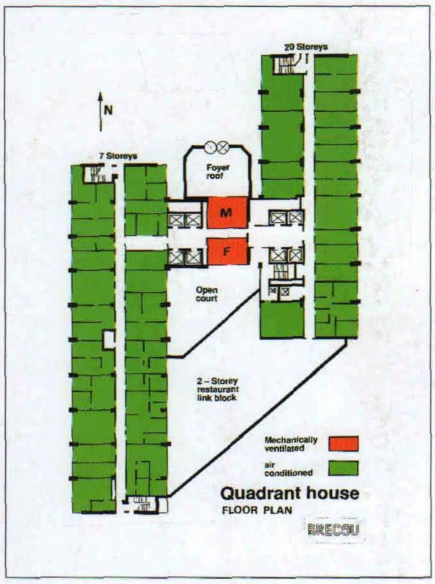
Case Study 18

Energy efficiency in offices

Quadrant House, The Quadrant, Sutton, Surrey. Energy efficiency in a 1980 high-rise through upgrading and energy management

- Room heat pumps transfer heat from warm to cool areas via warm water circuit
- Plant upgraded and energy costs much reduced using contract energy management
- Electronic building and energy management system coordinates central plant and locally controlled room heat pumps
- Summertime electric hot water generation avoids inefficient use of boilers
- Electricity saved using electronic lighting controls
- Results have improved the energy consumption from the CIBSE Energy Code Part 4 'poor' level to 'good'





The Project

Quadrant House is a speculative air conditioned building completed in 1980. It is now the headquarters of Reed Business Publishing Group and accommodates a wide range of activities from editorial and advertising to photographic processing.

Two office towers of 20 and 7 storeys with roof plant rooms are linked by a 2-storey podium with ancillary accommodation and three staff restaurants.

Most offices accommodate between 1 and 10 persons and are seven metres deep to either side of a central artificially lit corridor There are also a number of open areas for up to 40 people.

The central air conditioning system sends treated fresh air to the rooms where local wall-mounted heat pumps supply or remove additional heat to suit individual needs, transferring it to or from a circulating water main. Any surplus heat in the main is rejected through cooling towers and any deficiency is made up by the boiler plant.

In 1987 Reed engaged Matthew Hall's 'Mastercare' contract energy management service to run the building services. This included taking charge of plant operation, maintenance repairs, replacements, fuel purchasing, and achieving specified environmental standards.

The Result

The contract allows the contractor to invest its own time and money to achieve energy cost savings, and share the benefits with the client.

Here Matthew Hall Mastercare installed new burners and replaced the electronic Building Energy Management System (BEMS) and related controls.

Between 1985/86 and 1988/89, the new human and electronic systems reduced gas consumption to one-third, with two main areas of saving:

- controlling the central air handling plant to minimise the heat surplus or deficiency from the heat pumps
- eliminating inefficient use of boilers in summer by heating hot water for catering and toilets electrically.

Just before the energy management contract started, automatic lighting controls had also been fitted, plus local switches for the light in each office instead of large gangs of switches in the corridors.

The improved plant and lighting management has cut electricity use by 15%, in spite of growth in electronic office equipment and summertime electric hot water heating.

"Improved plant and lighting management has cut electricity use by 15%"

BEST PRACTICE PROGRAMME

Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

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Overview

The building has a fully conditioned fresh air system with room heating and cooling by Versatemp heat pump units at approximately 3 metre intervals on external walls. The heat pumps extract or dispose of heat to a water circuit at about 27°C, allowing heat to be transferred from hot to cold rooms. Any overall heat deficiency is met from the boilers and any surplus is rejected through cooling towers on the roof.

Heating

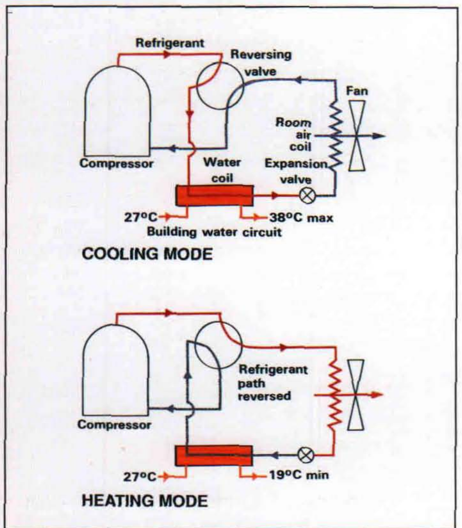
Two 2.5MW cast iron boilers (fitted with new gas burners in 1987) provide hot water for ventilation plant heater batteries, the heat pump circuit (via a heat exchanger), and compensated perimeter heating for the restaurant area. They operate under optimum start/stop control from 7.30am to 7.30pm with pump run-on to 7.45pm.

The toilets are heated and mechanically ventilated by independent supply and extract plants.

Air Conditioning

Two main Air Handling Units (AHUs) on top of the low block provide conditioned primary air to the main office spaces. The BEMS controls supply air temperature, enthalpy, and fresh/recirculation air ratio. The main chillers which serve the AHUs run for only four months of the year.

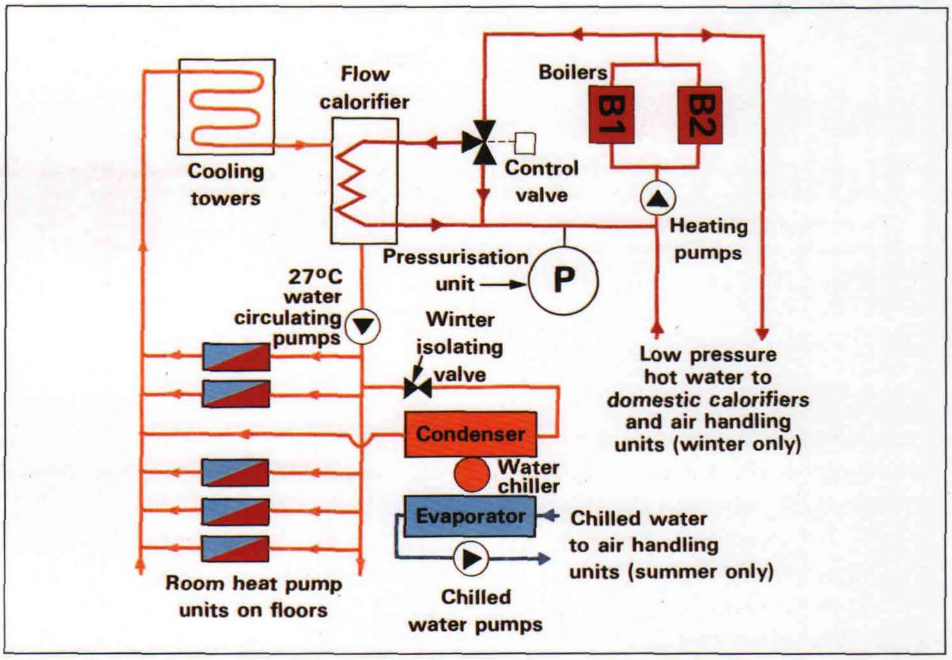
An independent chiller and multizone air handling unit on the first floor roof serves a dual-duct system for the restaurant and the 19th floor has a separate all-air heat pump system.



Room Heat Pump Operation

Domestic Hot Water

Toilets etc are compactly grouped and supplied from two centrally placed calorifiers on the seventh floor. The first and nineteenth floor restaurants have their own local calorifiers. In summer, the boilers are isolated and the calorifiers are electrically heated.



System Schematic

Lighting

General office lighting uses 1800mm recessed twin tube luminaires giving about 450 lux for a 17 W/m² installed rating. The use of better reflectors — which allow similar light levels to be obtained with half as many tubes — is now being considered. Restaurant and reception areas have more varied lighting, including many tungsten reflector bulbs, which raises the average installed load in the building to 20 W/m².

Originally lights in all the offices were controlled from large switch panels in the corridors, and naturally many lights were switched on and left on unnecessarily.

In 1985 automatic lighting control was installed, together with local manual over-ride switches for each light in each office. Interchangeable "Coding plugs" fitted to each group of lights identify the time and daylight-linked programmes to which they should respond.

All lights except security lights (typically one per office) are turned off at 1pm and hourly after 6pm. In addition, when daylight is sufficient, perimeter lights are switched off in mid morning and mid afternoon.

Since the internal corridors were somewhat over-lit (this is quite a common fault) the automatic controls are also arranged to light two out of every three fittings in the day and one at night.

Catering

Catering equipment is conventional medium duty gas. The main kitchen serves about 600 meals per day of which about 200 are salads. The 19th floor kitchen serves a variable number up to 250.

Electronic Energy Management System

Apart from the room thermostats for the unit heat pumps — which are under the control of individual occupants — all other environmental services control and management functions are carried out by a Trend 921 Building and Energy Management System (BEMS) with ten intelligent outstations.

As well as the normal time, optimum start-stop and monitoring functions, the BEMS controls the primary air temperature to minimise the amount of additional heating or cooling required from the heat pumps. This improved management has dramatically reduced gas consumption and made worthwhile savings in cooling energy. Several control strategies were tried.

Initial Strategy

Initially supply air temperature was adjusted to maintain return air temperature at a constant level, with a correction from the temperature differential in the heat pump circuit (eg: the more the heat pumps were cooling the more the primary air temperature was dropped).

Ultimate Strategy

Ultimately it proved more effective and economical to schedule supply air temperature against outside air temperature (13°C supply at 24°C ambient and 22°C supply at 0°C), while maintaining the Versatemp circuit influence. For early morning preheat this schedule is overridden to allow the building to be warmed up rapidly.

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Building Team

Architects	Wimpey
Services Engineers	Wimpey
Mechanical Installation	Towco Gratte
Operation	Matthew Hall Mastercare

Building Details

2 linked office blocks completed in 1980. High block with 20 floors, roof plant room, basement plant and service area. Low block with 7 floors and roof plant room. 2 storey link block.

Gross floor area	25760m² 277300ft²
Treated floor area	23475m² 252700ft²
Nett floor area	17210m² 185300ft²
Typical occupancy:	1000 out of 1300 staff

Typical hours of use: 8am-7pm weekdays with limited occupancy to 9.30pm and occasional weekend use.

Fabric	**U-value (W/m²K)**
Walls (brick plinth/concrete panels)	0.6
Roof (1.2 where over plant rooms)	0.6
Windows (aluminium clear double)	3.3

Solar protection. Lightly tinted glass with internal blinds on E, S and W faces and a heavier tint on the lower two floors.

Heating

Cast iron boilers 2 × 2500 kW serving air handling units, domestic hot water and heat pump water circuit.

Optimum start/stop for occupancy 7.30am-7.30pm.

Boilers valved off from mid May to mid October. New burners fitted in 1987.

Hot Water

Two calorifiers for toilets and two for kitchens: heat from boilers in winter, electric in summer.

Air Conditioning

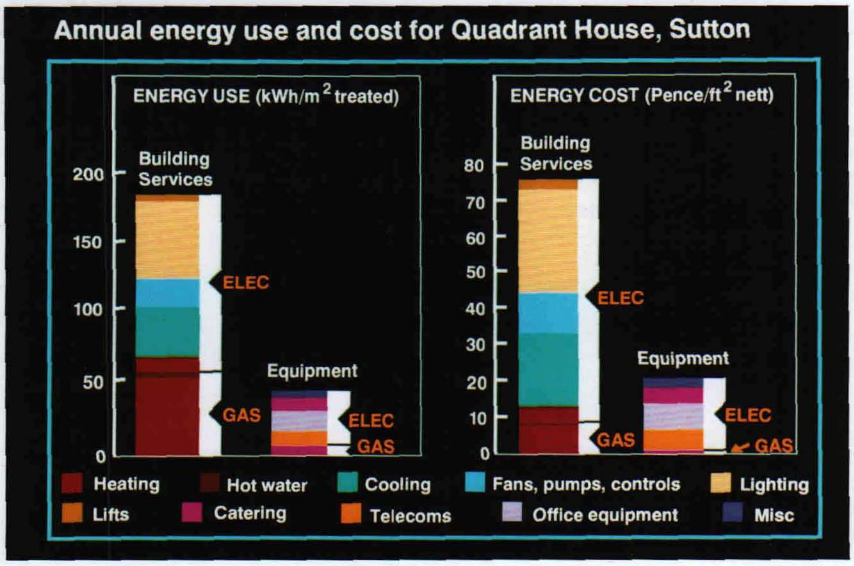
870 Versatemp local heat pumps with individual thermostats. Fully conditioned primary air from two main plant rooms. Heat from boilers, chilled water from 180kW reciprocating chiller. Spray humidifiers. Heat rejected from heat pumps and chillers to cooling towers via common water circuit. Separate dual duct systems for restaurant.

Energy Management

Central control and monitoring by BEMS, including optimisation of primary air and heat pump water temperatures.

Analysis of Energy Use and Energy Cost

From October 1987 to September 1988 the building consumed 1,460,000kWh of gas and 3,800,000kWh of electricity. The total of 224kWh/m² of treated area is well within the CIBSE Energy Code Part 4's "good" category for an air-conditioned office of this size.



The diagram above shows the breakdown of annual energy use and cost. As a result of the energy management measures, the cost of gas (£16,200) is now one-tenth of electricity (£161,400) — 8.7 and 87 pence per square foot nett respectively.

■ Heating 61kWh/m²
52kWh/m² gas
9kWh/m² electric

Heating energy use is low owing to the reasonable U-values, the local heat pumps which can recover local excesses of heat, and particularly the BEMS control with careful attention by the operators to primary air and water circulation temperature in order to minimise simultaneous heating and cooling. This improved control and management, together with electric heating of hot water in summer, has cut gas consumption to one-third of its 1985-86 level.

■ Hot Water 4.5kWh/m²
3.5kWh/m² gas
1kWh/m² electric

Hot water energy use is small for a building of this size with substantial catering kitchens: economies arise from tight control, a compact distribution system and summertime electric heating which avoids the losses which occur when using heating boilers for hot water only.

■ Cooling 35kWh/m²

The cooling load includes 26 kWh/m² for the Versatemp heat pumps. The main office chillers use only 5 kWh/m² because they chill the primary air only: the heat pumps reject their heat direct to the cooling towers.

■ Fans, Pumps, Controls 21kWh/m²

Consumption is modest for a fully air conditioned building, largely because an air/water system such as this requires lower air turnover rates (and hence less fan power) than all-air systems, but it also reflects the tight operating schedule.

■ Lighting 55kWh/m²

Twin 1800mm fluorescent fittings give installed ratings of 17 W/m² for offices (illuminance 450 lux) and 30W/m² for corridors. The overall average, with decorative lighting, is 20W/m².

An automatic ECS control system sweeps perimeter lights off at 10am and 1pm if daylight is sufficient, and switches most internal lights off hourly after 6pm. Together with local switches, this has reduced lighting energy use by about one-third, though the kWh/m² figure is still relatively high.

■ Catering 15kWh/m²
7kWh/m² gas
8kWh/m² electric

At about 1.8kWh per meal, energy use is relatively low for this scale of catering, indicating efficient operation and a high proportion of cold meals.

■ Office Equipment 13kWh/m²

The amount of office equipment and its energy use is about average.

■ Telecommunications 10kWh/m²

This unusually high figure is largely the result of an early electronic exchange based on mainframe computer equipment in a computer room environment.

■ Miscellaneous 10kWh/m²

Energy use by lifts and document conveyor (5kWh/m²) is average for a building of this height. The balance is accounted for by external floodlighting (3kWh/m²) and a photographic studio.

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User Reactions

The building provides a good working environment, helped by the individual room temperature controls on the Versatemp heat pump units which give occupants the freedom to adjust conditions as they require.

The automatic lighting controls have caused some adverse reaction when lights go off during late night working or in perimeter areas where natural light is not sufficient locally (eg: blinds drawn to counteract glare). The problems have usually been dealt with by changing coding plugs and time programmes, and by installing a few extra local switches.

General Appraisal

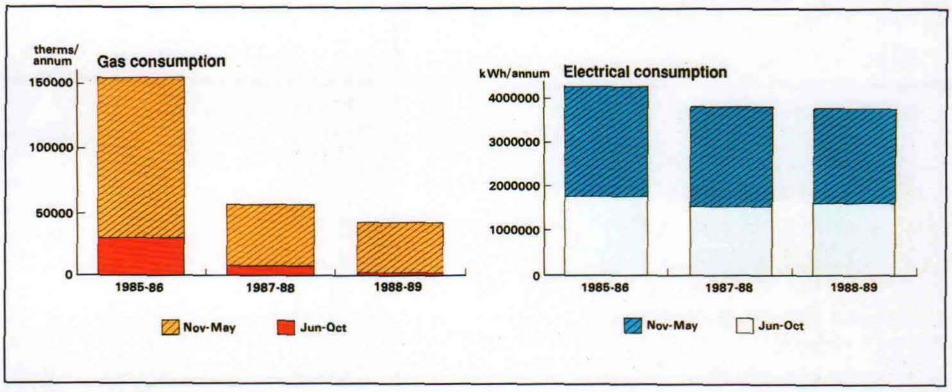
In the early 1980s the energy consumption of this building was worse than average and it would not have been considered for a case study. But now good maintenance and management — together with the new electronic control and energy management systems — have realised substantial and cost effective savings.

Gas consumption has been cut to one-third by a combination of good practice and sophisticated control, and in particular:

- Careful control of primary air temperatures to minimise the use of the room heat pumps for heating and cooling.
- Getting the optimum start and stop arrangements right: for instance the offices often stay warm enough if the boilers go off at 4.30pm.
- Avoiding inefficient summertime boiler operation by heating domestic hot water by electricity from May to September.

Electrical savings have also been achieved despite growth in office equipment and transfer of summertime hot water heating to electricity by:

- Ensuring that pumps, fans and cooling towers only operate when needed.
- Optimising the temperature of the primary air to minimise subsequent reheating or re-cooling by the Versatemp room heat pumps.
- Ensuring that the chillers are off for as much of the year as possible, by direct evaporative cooling of the heat pumps' water circuit.
- Introducing and refining the automatic lighting control system.
- Reducing the wattage of decorative tungsten lights in the restaurant and reception areas, and replacing them with miniature fluorescent lamps in toilets etc.



Annual Fuel Consumption

Contract Energy Management

The "Mastercare" energy management contract has allowed sufficient expertise and incentive to be brought to bear on this complex installation to achieve much improved energy efficiency without compromising environmental conditions and user satisfaction.

Building users primarily require a satisfactory environment, and the client therefore asked for room temperature control to be excluded from the energy management contract, and left in the hands of the occupants.

Interior view of an office

Some people might have expected such individual control to have increased running costs significantly, but the heat pumps can cope efficiently with varying local heating and cooling demands by transferring heat across the building. Careful attention to the control functions of the electronic energy management system has ensured that the main plant responds efficiently both to changes in external conditions and to the overall demands of the room heat pumps.

The overall result has taken the building's annual consumption from "poor" to "good" as defined in CIBSE Building Energy Code Part 4.

Main Conclusions

The project demonstrates:

- The considerable scope for making cost effective energy savings in existing commercial buildings through improved control and energy management, and conversely the waste that can occur if complex and potentially efficient systems are not effectively managed.
- That a high level of individual control is not incompatible with good economy if the associated central plant is also managed efficiently to respond to user demands.
- That considerable savings can result from automatic lighting controls and local switches in daylit offices when control strategies are developed in cooperation with occupants.
- That good contract energy management can potentially allow a complex building to be run with an efficiency beyond the capability of many occupiers and maintenance contractors. With this style of shared savings contract, the client's capital and management resources are safeguarded while the contractor is able to make cost effective energy saving investments at his own risk; and pass on some of the benefits directly to the client.

Short Notes on the Measurement of Floor Area

Gross	Total building area measured inside external walls.
Nett	Gross area less common areas and ancillary spaces. Agent's lettable floor area.
Treated	Gross area less plant rooms and other areas (eg stores), not directly heated.

PRECISE DEFINITIONS ARE AVAILABLE ON REQUEST

All case study analyses in this series are based on at least one year's measured fuel consumption and cost. Further breakdown into sub-headings is by a combination of sub-metre readings, on-site measurements and professional judgement. The technique of apportionment is the same for each Case Study and all quoted building areas have been re-measured for the project.

This study has been carried out by the Davis Langdon & Everest Consultancy Group and William Bordass Associates. The cooperation of the owners, designers, managers and the occupants of the case study building is gratefully acknowledged.

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